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SUPPLEMENTARY HYPOTHESIS RESPECTING THE ORIGIN OF THE LOESS OF THE MISSISSIPPI VALLEY.[1]

THE loess problem still remains obstinate. While it has yielded somewhat to progressive research, there is, I think, a nearly universal feeling of dissatisfaction with all theories thus far advanced. The eolian hypothesis appears to be the better supported so far as concerns the chief deposits of China and perhaps some of those of western America, while the aqueous hypothesis seems best supported so far as concerns the deposits of the Mississippi valley and western Europe. It is the judgment of some students that the ultimate solution will lie in the recognition of both hypotheses, but the means of discriminating between the two and of applying the criteria are as yet wanting. The present paper is intended to be a contribution in this direction. It is confined to the loess deposits of the Mississippi valley, but is probably applicable to the loess of western Europe.

The distribution of the loess in the Mississippi valley seems to be very significant in its peculiarities. These may be summed up in two great features.

1. The loess is distributed along the leading valleys. These embrace not only the great valleys, the Missouri and the Mississippi, but some of the subordinate valleys, as the Illinois, the Wabash, and others. The loess is found along the Missouri River from southern Dakota to its mouth; along the Mississippi River from Minnesota to southern Mississippi ; along the Illinois and the Wabash from the points of their emergence from the territory of the later glacial sheets to their mouths. Along these valleys the loess is thickest, coarsest and most typical in the bluffs bordering the rivers and grades away into thinness, fineness and non-typical nature as the distance from the rivers

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[1] Read before Section E, Am. Asso. Adv. Sci. Aug. 12, 1897.

increases. In some instances the loess mantle rises to the divide and connects with the similar deposit of an adjacent valley, but the law of progressive fineness and thinness still holds. This relationship is such as to create a very strong conviction that the deposit of the loess was in some vital way connected with the great streams of the region.

2. The second significant feature is the distribution of the loess along the border of the former ice-sheet at the stage now known as the Iowan. (Strictly speaking there was more than one stage of loess formation, but for convenience only the main stage will be here discussed.) The elaborate paper of McGee made us familiar some years ago with this relationship in eastern Iowa. The studies of Calvin and his colleagues, Bain, Beyer, and Norton, of the Iowa Survey, of Winchell and Upham of the Minnesota Survey, of Todd of the South Dakota Survey, and of Salisbury, Leverett, Udden, Buell, Hershey, and the writer of the United States Survey, have greatly extended the evidence of this relationship. It has recently been much advanced by the Iowa geologists and by Leverett and Hershey in northwestern Illinois. Next the border of the ice-sheet the loess is thick and typical, but graduates away with increasing distance from the ice border in a manner similar to the graduation away from the river valleys. On the border next the ice there are developed the formations designated by McGee paha, elongated domes of quasi-drumloidal contours which are mantled by loess. This superficial loess graduates downwards into loess of coarser and coarser texture until it often passes into a nucleus of sand. Below this there is often an embossment of till. These pahas seem to be ice border phenomena. Whatever their special mode of formation their distribution seems to connect them in some more or less direct genetic relationship with the ice.

It has been affirmed by several independent observers that the loess graduates into glacial clays and glacial till and this relationship further tends to confirm the association of the loess with glacial action.

It has been shown by the microscopical examinations of

Salisbury that the loess particles are composed in part of feldspars, amphiboles, pyroxenes and other common constituents of the glacial clays. These silicates are decomposable under prolonged weathering, and hence cannot well be supposed to come from residuary clays under the ordinary conditions of the Mississippi valley. The presence of the calcium and magnesium carbonates, independent of the presence of shells, points in the same direction. This inference is strengthened in a peculiar way by observations in the lower Mississippi valley. Above the Lafayette gravels and below the loess there is a stratum of silt which does not habitually contain the characteristic silicate particles of the loess. This stratum has been by most observers associated with the loess, but it is separated from it by a soil horizon as abundantly affirmed by the observations of Salisbury and the writer. On the other hand it graduates more or less freely into the Lafayette sands and gravels. The stratum is, as we interpret it, the last deposit of the Lafayette stage. It is a typical finishing deposit succeeding a fluvial sand and gravel. Now this has special significance in this relationship, in that it shows that in the stage closely preceding the loess deposit, the Mississippi did not lay down silts of the same constitution as the loess. The inference therefore is that the loess is not simply a fluvial silt brought down from the surface of the river basin, nor common wind drift borne into it, but that it had a special origin connected with glacial action which was competent to supply precisely the kind of silt of which the loess is made.

It is hard to resist the force of this argument from the constitution of the loess taken in connection with the two distributive relationships. Jointly they seem to force the conviction that the loess had its origin in some relationship to the ice of the Iowan stage and to the rivers that led away from the ice edge at that time.

But the hypothesis that the loess is simply an outwash of glacial grindings distributed along the river valleys by the glacio-fluvial waters is attended by grave difficulties. This remains true whether the deposition be supposed to have taken place either in a strictly fluvial fashion, or in a fluvio-lacustrine fashion, or in a true lacustrine fashion, or in an arm of the sea. In the first place, the vertical distribution of the loess cannot easily be explained. The extreme vertical range is not far from a thousand feet. The range within a score of miles is frequently from 500 to 700 feet. The loess sometimes seems to the field observer to have a special fondness for summit heights. It sometimes mantles topography of a pronouncedly rolling type. It does not then appear to be a deposit which once had a level or even a smooth surface out of which the rolling surface has been eroded, but to be a mantle laid down upon a previously undulatory surface. Such a mantle might perchance be laid down from water, but I am not aware that we have any demonstrative deposition of the kind which closely simulates the mantling of the loess in some of the upland territory. To suppose that the Mississippi, Missouri, Illinois, Wabash and lower Ohio rivers were so swollen that they united over their divides and threw down a mantle of fine silt over the southern and western half of Iowa and the southern parts of Illinois, Indiana and Ohio, is a somewhat severe tax upon belief. It is difficult to imagine the conditions which should have maintained such a body of water. This has been so much discussed that I need not dwell upon it. But even if such a body be supposed, it is difficult to imagine how the deposition could have been precisely what we find in the case of the loess. It is futhermore difficult to account for the presence of the land shells which abound in it; for if this great flood had the ice-sheet for its northern border, it is extremely difficult to imagine how it could have been peopled so widely with the terrestrial mollusks.

The limit of the loess does not appear to be a strictly topographic one. It is difficult to bring its border into strict accord with a horizontal plain as required by the lacustrine and marine phases of the hypothesis, or even into a consistent gradient as required by the fluvial phase, without an arbitrary warping of the surface. The spread of the loess in the lower Mississippi valley is more extensive and reaches greater heights on the east side than on the west side, so far as present knowledge goes. A similar fact seems to be true of the Missouri valley. I think this is generally true, but my observations are not sufficient to justify its unqualified affirmation as a generalization.

There are other difficulties attending the aqueous theory in its simple application, but I need not attempt an exhaustive recitial here as they have received emphasis in the long battle between the eolian and aqueous hypotheses. The foregoing will I trust suffice to show that there is abundant occasion to still cast about for a more satisfactory explanation of the loess puzzle.

The supplementary hypothesis herewith proposed attempts to divide the honors between the aqueous and eolian agencies. It recognizes the tremendous force of the arguments from the distribution and the constitution of the loess in favor of the glacio-fluvial hypothesis, and it adopts that hypothesis as the fundamental explanation of the origin of the Mississippian loess. It assumes the presence of the Iowan ice at the chief stage of loess deposition. It assumes a very low slope of the land and a consequent wide wandering of the glacial waters. It assumes the development of extensive flats over which the silts derived from glacial grinding were spread. It assumes that the glacial waters were subject to great fluctuations; 1° as the result of periods of warm weather in the melting season, and 2° as the result of warm rains, which not only added directly to the volume of water, but forced the rapid melting of the ice. Gilbert has acutely observed that there is no way in which the atmosphere can convey its heat energy to a glacier so effectually as through warm rains.

Let it be imagined, therefore, that the silty waters from the margin of the ice-fields wandered over broad flats and constantly built them up by their sediments, and that at periodical flood stages they extended themselves widely over the plains, while between the flood stages they withdrew to more limited courses.

The territory covered by the maximum extension of the waters would be the zone of accumulation of fluvial loess. It is not necessary to suppose that the periodic extensions of the floods were destructive of the vegetation over all the flat region. In some portions not only could vegetation persist, but the land mollusks and other animals dependent upon the vegetation could find a temporary retreat from the flood on the taller vegetation that may have prevailed.

After each of the periodical retreats of the water there would be left extensive silt-covered tracts facily exposed to the sweepings of the wind and from these, when dried, dust could be derived in great quantities to be borne away over the adjoining lands and lodged in their vegetation. The material thus derived would be essentially identical with the glacio-fluvial deposition, and thus the hypothesis seeks to account for the glacial element in the constitution of the eolian portion of the loess. The presence of land mollusks in the upland eolian loess finds in this way a ready explanation, while their presence in the lowland loess mingled with aqueous mollusks finds an almost equally obvious elucidation ; for not only would the upland shells be washed into the lowlands, as we observe they are at the present time, but they would periodically invade the lowlands in the intervals between submergence and would be caught and buried there. Occasionally the shells of the lowland and aqueous mollusks would be borne to the uplands by organic agencies, and possibly in rare instances by the severest type of winds, and hence their occasional presence there is not remarkable.

To make this a good working hypothesis it would appear that there must be an accommodation between the breadth and fluctuations of the fluvial deposits and the extent and massiveness of the eolian deposits, for if we suppose the glacial floods to be confined within narrow channels, the sweeping ground of the winds would have been too scant to give origin to the great mantle of silt then attributable to them, for we must remember that in proportion as the river work is narrowed the wind work is expanded. It is obvious that the eolian factor will cut away its own ground if pushed too far.

There is little question that loess-like accumulations are now taking place on the bluffs adjacent to the Mississippi and Missouri valleys. Observation seems to clearly indicate this. But such accumulations are relatively scant in amount and limited in extent, and it is difficult, if not impossible, to believe that the great loess mantle had its origin from the wind drift of flood plains no more extensive than those of today. It must be constantly borne in mind that the eolian deposits are measured, not by the quantity of silt borne by the winds and lodged on the surface, but by the *difference* between such lodgment and the erosion of the surface. Under most conditions with which we are familiar the erosion is more than a match for the dust accumulations. The conditions must then have been extraordinary which would give a dust deposition sufficient to supply erosion and still leave so large a residuum as the loess mantle implies. The unleached and relatively unweathered nature of the body of the loess is specially in point here. These considerations warn us of the theoretical danger of too greatly circumscribing the fluvial action.

On the other hand, if we attempt to extend the fluvial hypothesis too greatly we fail to leave sufficient feeding ground for the molluscan life and we encounter the topographical and physical difficulties which have been previously urged against the pure aqueous theory. A Janus-faced hypothesis is here offered in the hope that by a judicious reference of a part of the loess to one class of action and a part to the other, a joint explanation may be found to afford a true elucidation of the perplexing formation. At any rate, it has seemed worth while to propose the hypothesis for trial. It will doubtless be extremely difficult to find a line of demarkation between the two classes of deposits. Such attempts as have been made in this line justify this apprehension. This supplementary theory has been in mind for several years and was briefly suggested in my paper on the *Genetic Classification of the Pleistocene Deposits*, presented at the Fifth Session of the International Congress of Geologists at Washington in 1891.[1] An effort has been made by some of my colleagues and by myself to find criteria of discrimination between aqueous and eolian loess. While individual types of both deposits are not difficult to find, a criterion or a series of criteria of general applicability which shall distinguish the two and assign to each its appropriate part is yet wanting.

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[1] Compte-Rendu of the Fifth Session of the International Congress of Geologists, Washington, 1891, p. 192.

Richtofen in his classic work on China urged as the explanation of the great Chinese loess an eolian hypothesis supplemented by a fluvio-lacustrine hypothesis. He insisted that the original and chief loess deposits were formed by dust blown from the great arid plateaus and lodged on the more fertile plains of China, and that from these primary deposits the streams gathered and subsequently redeposited in fluvial or lacustrine form a subordinate portion, thus giving origin to a secondary loess formation. Going beyond that field he and his supporters have apparently tried to apply this secondary factor to the explanation of difficulties in the European and American loess, to which its application is more than doubtful. It is interesting, however, to note that the loess puzzle of China, even in the mind of its chief exponent, finds a full solution only in a combination of eolian and aqueous hypotheses. The present writer herein urges the trial of a similar combination of hypotheses, but reverses the order of the terms in their Mississippian application. The aqueous loess is made primitive and the eolian loess secondary. The Richtofen loess may be said to be first eolian and secondarily aqueous; the Mississippian loess, first aqueous, and secondarily eolian. The Richtofen loess in its ultimate origin is residuary. The Mississippian loess, in its ultimate origin, is glacial. The Richtofen mode of origin may be said to be eolio-fluvial, the mode herein advocated, fluvio-eolian, in which terms the order of the words indicates the order of derivation and each word signifies a variety of loess.

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